TACTUAL SYMBOLS FOR THE BLIND

FINAL REPORT: OVR-RD-587

Carson Y. Nolan & June E. Morris

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Mr. W. C. Gill, Superintendent-Principal

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Mr. J. H. Wallace, President
Mr. W. S. Davis, Principal, Blind School

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Dr. A. G. Kloss, Superintendent
Miss Margaret Esch, Principal

Tennessee School for the Blind
Mr. E. J. Wood, Superintendent
Mr. O. R. Denton, Principal

Kentucky School for the Blind
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Mr. W. F. Davis, Principal

Rehabilitation of the blind requires embossed materials which employ both verbal and graphic forms of communication. Braille, which is highly developed and standardized, fills the requirement for embossed verbal communication. However, the means available for embossed graphic communication, i.e. maps, graphs, charts, and diagrams, are still relatively crude. Lack of identification of clearly discriminable tactual symbols and lack of knowledge of factors that determine tactual figure-ground relations have seriously impeded development in this area.

Three types of symbols; areal, linear, and point, are needed for graphic communication. The number of discriminable tactual symbols possible in any given size appears dependent upon the medium in which symbols are reproduced. For example, the number of small symbols which can be reproduced through embossing paper is extremely limited. Heath (1958) explored the usefulness of Virkotype printing for the reproduction of tactual graphics and successfully identified discrete tactual symbols for area. However, methodological problems restricted the number of discrete symbols identified to below an acceptable minimum. Morris (1960) and Morris and Nolan (1961) replicated Heath's work and were able to identify eight discrete symbols for area. Morris and Foulke (1960) described the successful learning and retention of associations between these tactual symbols and sets of auditory symbols.

The purpose of this project was to identify and study sets of highly discriminable symbols for graphic representation of lines and points. The initial effort, carried out during September 1960 - August 1961, utilized Virkotype printing as a medium and was not successful. Therefore, a new medium, vacuum formed plastic, was selected and the earlier discrimination studies were replicated during the period September 1961 - August 1962. In addition, studies of associative learning and retention using these symbols were conducted.

General Methodology for the Discrimination Experiments

Purpose:

1. To empirically establish the comparative degree of discriminability of tactual symbols (for points and lines).

2. To determine if differences to discriminate these patterns exist between different groups of blind children.

Hypotheses:

1. There are no differences in ability to discriminate tactual symbols among blind children at different educational levels.

2. There are no differences in ability to discriminate tactual symbols among blind children according to sex.

3. There is no relation between blind children's chronological age and their ability to discriminate tactual symbols.

Subjects: The subjects were grouped by grade level and sex so that the effects of these variables on discriminability of the symbols could be determined. Only legally blind children whose vision was no greater than light perception were included in the study. All subjects were Braille readers who, in the opinions of their teachers, were doing acceptable school work at the level of grade assignment.

Procedure: The discriminability of the symbols was tested using the method of pair comparison. Every symbol was paired with itself and every other symbol resulting in $n(n - 1)/2 + n$ combinations of stimuli for each set studied. Each pair of stimuli was mounted on a 5" x 8" card. The serial order of occurrence of the pairs was randomized using a table of random numbers.

The task for each subject was to judge whether the stimuli in each pair were alike or different. Subjects were tested individually. No time limits for judging each pair were set.

Criteria for acceptance of a symbol as discriminate were (1) that average confusion with other acceptable symbols should be 5% or less and (2) that confusion with itself or any other single symbol acceptable by criterion (1) should be 10% or less. In addition, for any set of symbols acceptable by criteria (1) and (2), there should be no significant differences in discriminability of acceptable symbols among children in grades ranging from 4 through 12.

Data Analysis:

1. The total number of errors in judgement was computed for:
   a. Each pair of symbols.
   b. Each tactual symbol.
   c. Each subject.

2. Proportion of errors to the total number of judgements was computed for:
   a. Each pair of symbols.
   b. Each tactual symbol.

3. A two-way analysis of variance design was used to determine if significant differences existed between groups on the basis of sex or educational level. Differences at the 5% level of confidence were taken as significant.

4. A product-moment correlation coefficient was computed for total number of correct judgements per subject and chronological age.

General Methodology for the Associative Learning Experiments

Purpose: 1. To determine if the blind can learn to recognize tactual symbols.

2. To determine how well the blind can recall tactual symbols.

3. To compare tactual symbols for discriminability and ease of recognition learning.

Hypotheses:

1. No differences exist among blind individuals in:
   a. Their ability to learn to recognize tactual symbols.
   b. Their ability to recall tactual symbols after a 28 day period.

2. No differences exist between tactual symbols in:
   a. The number of trials it takes blind students to learn to recognize them.
   b. The number of trials it takes to recall them after a 28 day interval.

3. No relationship exists between the degree of discriminability and learning time for tactual symbols.

Subjects: The subjects were 10 or more boys and/or girls from grades 6-12. All were legally blind with vision not exceeding light perception. All were Braille readers who, in the opinion of their teachers, were doing acceptable school work at the level of grade assignment.

Procedure: Only those symbols which met the criteria of discriminability described above were utilized as stimuli in the associative learning studies. An identical experiment was performed for each of the types of symbols studied for discriminability.

Acceptable symbols of any given type were reproduced on 5" x 8" cards. Each symbol was paired with a letter of the International Phonetic Alphabet. The task for the subject was to learn to associate the tactual symbol with its phonetic name.

Association Training. Each subject was given 10 series of trials for each of 10 consecutive days or until recognition of the set of symbols studied was perfect for two consecutive series of trials. The number of symbols in a series of trials for any given type depended upon how many symbols of that type met the criteria of discriminability.

The paired-associates method of presentation was employed. During the first two series for each type, the subject felt the symbol for 15 seconds after which time the phonetic name was presented auditorily. For the rest of the series, the subject was allowed 15 seconds to feel each symbol and give its correct name. At the end of this period the correct name was given auditorily and the next symbol presented. The order of presentation within each series was randomized using a table of random numbers.

Recall Training. This procedure duplicated that for association training except the procedure for the first two series of any given type symbol was omitted.

Data Analysis:

1. Draw learning curves for:
   a. Total group on all tactual symbols.
   b. Total group on each tactual symbol.

2. Draw recall curves for:
   a. Total group on all tactual symbols.
   b. Total group on each tactual symbol.

3. Analysis of variance between means of individuals for:
   a. Recognition learning series.
   b. Recall series.

4. Analysis of variance between means of symbols for:
   a. Recognition learning series.
   b. Recall series.

5. Compute the rank order correlation coefficient between symbols ranked on order of discriminability (Exper. I) and ease with which they were learned..

Research Conducted during the Period 1 September 1960 - 31 August 1961

Discriminability studies for 18 possible linear symbols and 18 possible point symbols were carried out during this period. Visual representations of these symbols are given in Figure 1. The symbols studied during this period were reproduced through the Virkotype printing process. Virkotype printing utilizes a plastic powder sprinkled on wet ink which, when heated, produces an embossed image with a height of approximately .0045 inches. Previous research (Heath, 1958) had indicated that this degree of embossage is clearly perceptible tactually to the blind.

The subjects, who were identical for both studies, attended the Texas School for the Blind and Indiana School for the Blind*. Since the general design for discrimination studies required sex and grade grouping, the 96 subjects were distributed as follows:

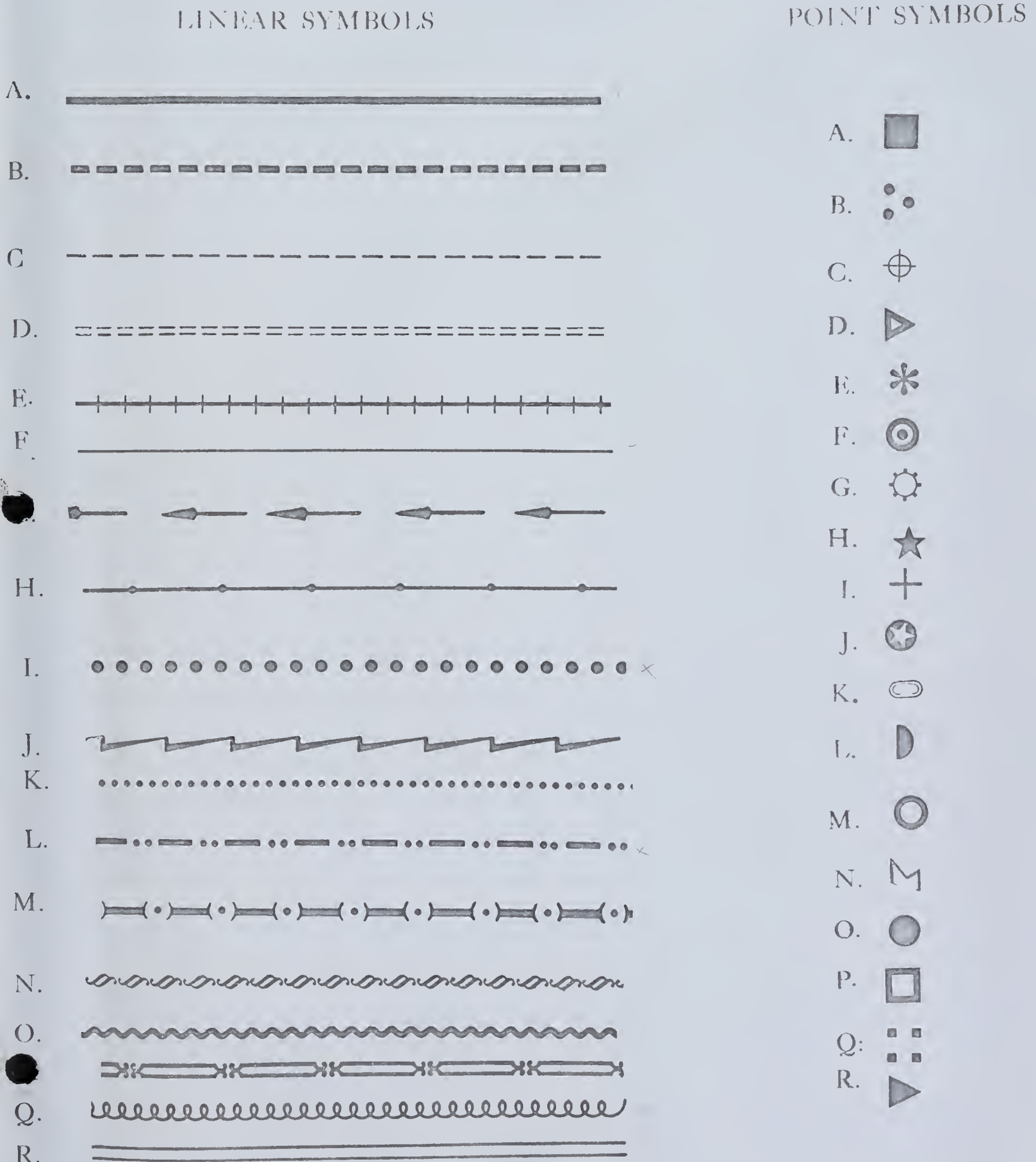
12 girls and 12 boys from grades 4 and 5.
12 girls and 12 boys from grades 6 and 7.
12 girls and 12 boys from grades 8 and 9.
12 girls and 12 boys from grades 10, 11, and 12.

All students enrolled in the above grades at the Texas School were used in the experiments. Where vacancies existed in the groups, subjects were randomly selected from appropriate grades at the Indiana School.

* A few students from Indiana also participated in a pilot study of procedures.

FIGURE 1

PATTERNS REPRODUCED IN VIRKOTYPE FOR POSSIBLE USE AS TACTUAL SYMBOLS.



Results:

Table 1 and 2 are matrices which give the percent of error in judgements of each symbol in comparison with every other symbol and with itself. An error for odd pairs is a judgement of "like" and an error for similar pairs is a judgement of "unlike". Inspection of the matrices reveals many pairs of symbols which fall within acceptable limits according to one of the criteria previously described. However, inspection also reveals that only four linear symbols and only one point symbol meet the criterion of 10% or fewer errors in comparisons with themselves. Therefore, neither set of symbols contains a number of acceptable symbols large enough for practical use.

TABLE 1

Percent of Error in Discriminating Difference or Likeness in Each of 171 Combinations of 18 Different Linear Symbols (N=96)

Lines	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A	11	11	26	05	04	94	14	69	01	08	08	16	01	11	07	07	01	04
B		16	60	35	07	12	17	14	06	15	60	73	02	43	46	02	02	02
C			20	27	02	24	42	27	02	18	64	52	08	10	38	09	00	02
D				29	17	03	02	11	05	12	46	27	14	19	54	16	08	05
E					28	00	04	04	03	09	14	04	42	15	19	05	18	04
F						07	25	80	01	14	10	10	00	08	11	05	02	02
G							24	32	06	24	11	16	03	02	08	05	01	01
H								17	01	15	14	14	01	12	11	04	01	03
I									02	07	03	03	11	07	08	02	02	01
J										24	09	12	14	06	18	06	01	01
K											07	32	04	35	46	07	01	00
L												19	10	45	51	00	01	01
M													30	27	07	08	18	03
N														35	47	05	22	04
O															12	12	07	02
P																18	14	65
Q																	11	06
R																		07

The errors in judging "like" symbols obtained in this study far exceed in size those reported by Morris (1960). One major difference existed between the two studies: Morris compared 12 symbols while the present study compared 18 symbols. In the study of Morris were 12 pairs of "like" symbols and 66 pairs of "unlike" symbols with correct "like" judgements constituting 15% of the total. In the present study were 18 pairs of "like" symbols and 153 pairs of "unlike" symbols with "like" judgements constituting almost 10% of the total. The possibility exists that the differential in the ratio of "like-unlike" responses was sufficient to introduce a response set toward "unlike" responses for subjects in the present study. It appeared essential to test this possibility before proceeding further.

TABLE 2

Percent of Error in Discriminating Difference or Likeness in Each of 171 Combinations of 18 Different Point Symbols (N=96)

Points	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A	18	02	06	03	07	05	03	01	03	01	02	08	00	01	18	48	02	03
B		24	00	02	03	01	00	09	01	01	00	02	00	05	02	00	20	06
C			39	08	67	32	18	28	08	16	18	08	07	01	19	01	02	05
D				43	08	11	00	09	08	06	08	14	02	06	19	02	02	42
E					30	30	08	34	15	09	14	12	04	12	09	01	02	07
F						21	23	16	06	53	12	06	15	01	22	04	02	01
G							17	04	01	78	02	02	82	02	26	10	01	01
H								43	07	02	10	11	01	12	05	01	04	10
I									53	00	07	03	01	04	03	01	02	10
J										19	02	01	70	01	56	11	00	02
K											20	04	00	06	02	02	00	03
L												57	01	03	16	01	02	09
M													09	03	39	12	02	01
N														36	01	02	02	10
O															24	05	01	09
P																23	02	01
Q																	20	02
R																		36

To this end the first study was replicated using 12 of the best symbols of each type. Analysis of the previous data had indicated that sex was not an important variable but that between grade differences may exist in symbol discriminability. Therefore, grade separations in the subject groups were retained. Forty-seven students in grades 4-12 of the Tennessee School for the Blind participated in the second study. Results are presented in Tables 3 and 4 which are matrices of percent of the total number of judgements in error for each combination of symbols.

Inspection of the data in Tables 3 and 4 reveals results similar to those previously obtained. However, no significant difference in discriminability by grade levels was found. Many "unlike" symbol pairs show error scores falling within the limits set by the criteria. However, when "like" combinations are considered, it is found that only five linear symbols and only five point symbols meet the criteria of 10% error or less. Again, these numbers of distinct linear and point symbols are too few for practical use.

Comparison of the frequency of errors for both "like" and "unlike" when 18 symbols are judged as opposed to 12 symbols yields a chi square of .06 for the line symbols and a chi square of 2.95 for the point symbols. Both these indices are below the chi square value of 3.84 required for statistical significance at the 5% level of confidence. Therefore, the hypothesis that a response set is involved is not supported.

Morris (1960) reported an equal proportion of errors for both "like" pairs (.09) of symbols and "unlike" pairs (.09). In the present study, when 18 symbols are compared errors for point symbols are 30% for "like" pairs and 8% for "unlike"

TABLE 3

Percent of Error in Discriminating Difference or Likeness in Each of 78 Combinations of 12 Different Linear Symbols (N=48)

Lines	A	B	D	E	G	I	J	L	M	N	Q	R
A	10	19	04	04	10	00	06	10	00	04	02	02
B		10	52	00	08	02	08	77	02	33	00	02
D			27	35	06	06	08	44	08	44	04	04
E				31	00	02	04	00	41	23	10	02
G					27	02	23	10	00	06	00	00
I						08	04	00	06	02	00	00
J							23	15	04	17	00	00
L								04	00	31	00	00
M									17	08	04	04
N										25	02	06
Q											10	12
R												15

TABLE 4

Percent of Error in Discriminating Difference or Likeness in Each of 78 Combinations of 12 Different Point Symbols (N=47)

Points	A	B	C	D	I	K	L	M	N	P	Q	R
A	21	00	02	02	11	02	04	02	00	30	00	11
B		08	00	02	00	00	00	00	00	02	21	02
C			28	08	06	13	17	04	00	00	00	02
D				51	23	02	19	02	02	00	00	34
I					42	06	06	00	06	00	00	08
K						08	02	00	00	00	00	00
L							42	04	00	02	00	23
M								08	04	19	00	02
N									45	02	00	11
P										04	00	04
Q											08	00
R												40

pairs and errors for line symbols are 18% for "like" pairs and 10% for "unlike" pairs. When 12 symbols are compared errors for point symbols are 26% for "like" pairs and 14% for "unlike" pairs and errors for line symbols are 17% for "like" pairs and 15% for "unlike" pairs. All the differences among "like" and "unlike" pairs in percent of errors made are significant at beyond the 1% level of confidence. The data indicate that some intrinsic characteristic of the symbols themselves may lead to confusion among "like" pairs.

Throughout the studies employing Virkotype printing as a medium, it had been apparent that visually detectable variation occurred in reproductions of the same

symbol. The effects of this variation were studied for areal symbols and appeared negligible because percentages of error for both kinds of comparisons were identical. Because linear and point symbols are by definition much smaller than areal symbols, small variations within symbols resulting from the production processes may have far greater effects. It was suspected that production variations within individual symbols were responsible for the greater proportion of errors within pairs of "like" symbols. If this were true, it appeared that confusion of "like" pairs would occur more frequently among highly sensitive subjects than among subjects low in sensitivity. A test of the relative number of errors for "like" and "unlike" pairs made by 20% of the group making the highest correct scores and 20% of the group making the lowest correct scores should serve as a check of this assumption. Table 5 gives comparative data from the first study which shows that the more sensitive group made a significantly greater proportion of errors on "like" pairs of both linear and point symbols.

TABLE 5

Comparison of Percent of Errors Made on Like and Unlike Pairs by 20 Subjects Making the Highest Total Number of Correct Judgements and 20 Subjects Making the Lowest Number of Correct Judgements

	Point Errors			Linear Errors		
Group	Like Pairs	Unlike Pairs	Total	Like Pairs	Unlike Pairs	Total
Best 20 Subjects	42%	58%	160	32%	68%	183
Poorest 20 Subjects	12%	88%	779	04%	96%	1144
	Chi Square 90.09*			Chi Square 163.03*		

* Significant beyond the 1% level of confidence.

These findings indicate that intra-symbol differences, resulting from the production processes, are great enough to contribute to a large proportion of error among the more highly discriminating subjects. This amount of error appears great enough to render symbols reproduced in the Virkotype medium impractical for everyday use. Therefore, the associative learning experiments were not carried out.

Research Conducted during the Period 1 September 1961 - 31 August 1962

The research during this period replicated the previous year's work utilizing a new medium, vacuum formed plastic, for the reproduction of symbols. The patterns to be studied were first reproduced in zinc through the photo-engraving process. A mold was then made by pressing the patterns into soft plaster which was then

allowed to harden. The patterns were next reproduced in .008 inch thick plastic through vacuum forming. This resulted in material embossed .018-.025 inches.

Once again, discriminability of linear and point symbols was studied simultaneously. The general experimental procedure described previously was followed and the number and grouping of the subjects was the same. The subjects were enrolled in the Florida School for the Deaf and Blind, the Louisiana State School for the Blind, and the Missouri School for the Blind. All students in grades 4 through 12 at the Florida School participated in the study. Students were chosen randomly from appropriate grade and sex groupings at the other schools in order to fill gaps remaining in the sample.

Discriminability of Linear Symbols

Thirteen possible linear symbols were studied. These are reproduced pictorially in Figure 2. Table 6 is a matrix giving the percentage of errors for judgements of each symbol when paired with itself or any other symbol. Symbols A, C, D, F, I, J, K, L, and M appear to meet the criteria for discriminable symbols previously described. From this group various combinations of several symbols (i.e. D, F, I, J, K, L, and M) meet the combined criteria in every respect.

TABLE 6

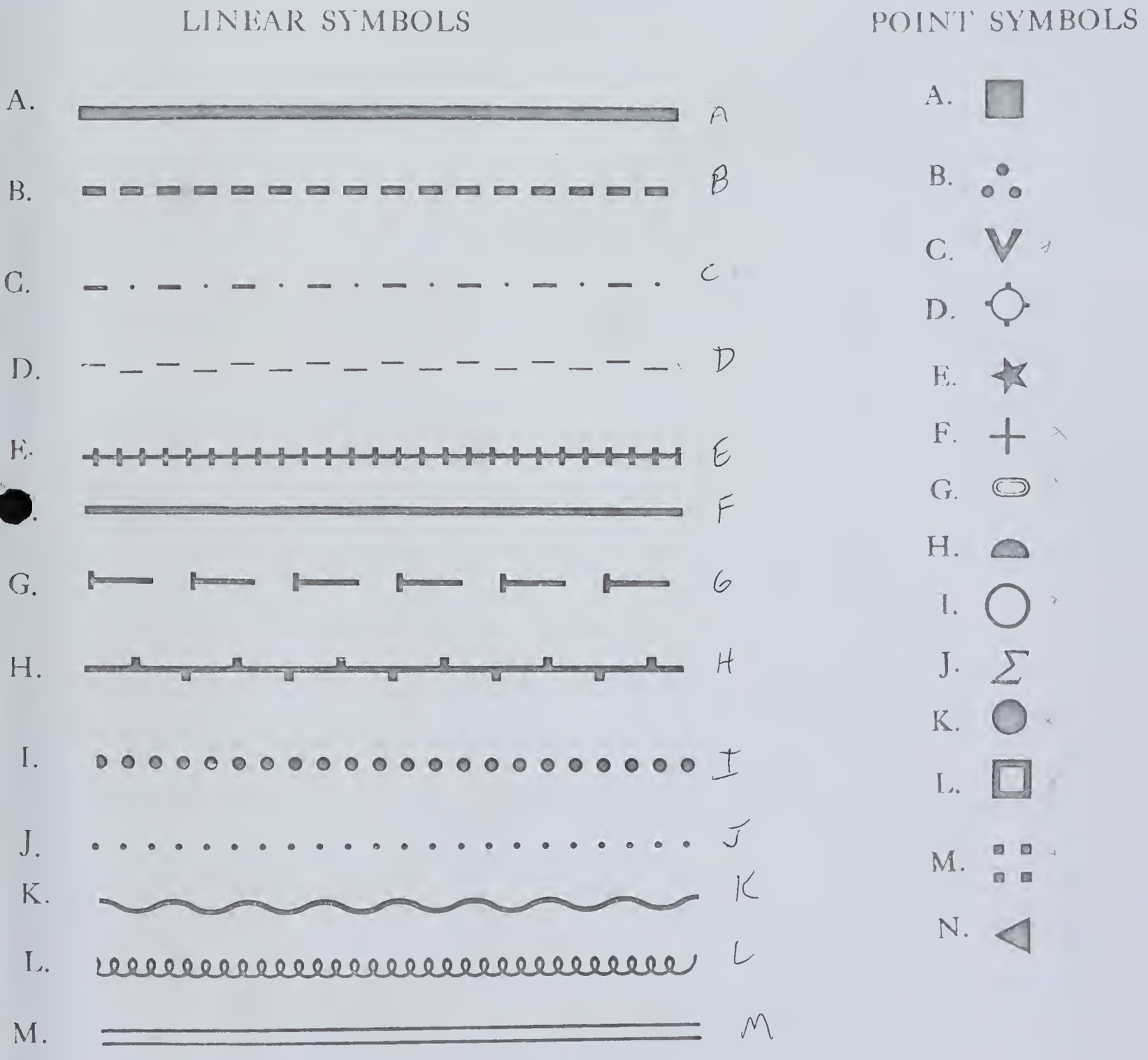
Percent of Error in Discriminating Difference or Likeness in Each of 91 Combinations of 13 Different Linear Symbols (N=96)

Lines	A	B	C	D	E	F	G	H	I	J	K	L	M
A	09	02	01	00	00	05	00	01	00	00	00	05	53
B		24	28	30	00	00	00	00	17	09	00	01	00
C			10	25	00	00	02	01	08	07	00	01	00
D				09	00	00	02	01	07	01	03	00	00
E					14	00	00	00	00	00	00	50	00
F						03	01	04	00	00	03	00	00
G							18	00	00	00	01	01	00
H								23	01	00	07	00	00
I									10	05	00	01	00
J										05	00	00	00
K											08	00	00
L												06	03
M													05

In the original research design, analysis of variance was to be used to determine whether differences existed in ability to discriminate symbols when subjects were grouped by sex and grade level. Throughout the studies of tactual symbols, no sex differences had been detected and because of this and the following problem relating to the distributions of the data this aspect of the analysis was discarded. As a result of refinement of symbols on the basis of the experience gained during the previous year's research, the distributions of numbers of correct judgements for individual subjects became markedly skewed toward the perfect

FIGURE 2

PATTERNS REPRODUCED IN VACUUM FORMED PLASTIC FOR POSSIBLE USE AS TACTUAL SYMBOLS.



score point on the error continuum. Therefore, analysis of variance techniques lacked applicability for analysis of the data. Table 7 gives the medians and ranges for the four grade levels of the experiment for number of correct judgements for presentations of the 28 possible combinations of the seven symbols indicated above as meeting all criteria of acceptability. The characteristics of the data mentioned above are quite obvious.

TABLE 7

Linear Symbols: Median Number of Correct Discriminations and Ranges of Correct Discriminations for 28 Pairs of 7 Acceptable Symbols for Subjects Grouped by Grade Level.

	Grades			
	4-5	6-7	8-9	10-12
Median	27.7	27.8	28.0	27.8
Range	25-28	23-28	26-28	25-28
N	24	24	24	24

Differences among the grade groups for ability to discriminate this series of seven symbols were tested for significance using the Kruskal-Wallis one-way analysis of variance by ranks (Siegal, 1956). The resulting H value was 5.43 which is considerably below the value of 7.82 needed for significance at the 5% level of confidence with 3 df. The correlation between chronological age and number of correct judgements was found to be .19 which just barely fails to be statistically significant at the 5% level of confidence.

Discriminability of Point Symbols

Fourteen possible point symbols were studied. They are reproduced pictorially in Figure 2. The matrix giving the percentage of errors for judgements of each symbol when paired with itself and every other symbol is presented in Table 8. Only symbols C, I, L, M, and N met the combined criteria for acceptability.

TABLE 8

Percent of Error in Discriminating Difference or Likeness in Each of 105 Combinations of 14 Different Point Symbols (N=96)

Points	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	16	02	00	05	00	00	00	01	02	01	03	18	01	01
B		12	00	00	02	03	00	00	00	01	00	00	03	00
C			07	01	01	01	00	00	00	02	00	00	00	04
D				19	03	02	00	00	06	00	07	36	00	01
E					24	29	05	00	00	03	00	00	00	04
F						25	01	01	00	03	01	00	02	01
G							17	57	00	01	02	00	00	06
H								21	01	00	01	00	00	09
I									04	00	22	10	00	00
J										20	00	00	00	00
K											11	04	00	00
L												04	01	00
M													03	00
N														08

Since a greater number of point symbols was needed it was decided to modify several of the patterns and gather additional data. Modifications were as follows: The horizontal arm of F was moved so as to make this pattern resemble the letter T; the overall size of G was increased by 20%; and the top of K which was initially flat became rounded.

TABLE 9

Percent of Error in Discriminating Difference or Likeness in the Revised Set of 14 Different Point Symbols (N=72)

Points	B	C	F	G	I	K	L	M	N
B	11	01	00	01	01	00	00	04	00
C		04	00	00	00	00	00	00	11
F			04	00	00	00	01	00	00
G				06	03	01	21	00	00
I					06	00	10	00	00
K						03	00	00	00
L							03	00	00
M								06	00
N									12

Discriminability of this set of points was tested using the following groups of students of both sexes enrolled in the Ohio State School for the Blind: 11 students in grades 4 and 5, 19 students in grades 6 and 7, 23 students in grades

8 and 9, and 19 students in grades 10, 11, and 12. An error matrix for the judgements of these students is presented in Table 9. It can be seen from inspection of this matrix that all symbols with the exception of L meet the combined criteria.

The situation previously described for testing grade and sex differences for the linear symbol data was duplicated here so identical modifications in data analysis were made. Medians and ranges for distributions of correct judgements by subjects within each grade group for the 21 pairs of acceptable point symbols are presented in Table 10. The significance of the differences between grade groups was tested using the Kruskal-Wallis test. The resulting H value was 3.81 which again fell below the value of 7.82 needed for significance with 3 df at the 5% level of confidence. The correlation between the chronological ages of the subjects and their discrimination scores was .03, a value which failed to reach statistical significance.

TABLE 10

Point Symbols: Median Number of Correct Discriminations and Ranges of Correct Discriminations for 21 Pairs of 6 Acceptable Symbols for Subjects Grouped by Grade Level.

	Grades			
	4-5	6-7	8-9	10-12
Median	21.0	21.0	21.0	21.0
Range	19-21	18-21	19-21	20-21
N	11	19	23	19

Recheck on Discriminability of Areal Symbols

Morris and Nolan (1961) previously had identified eight discriminable symbols for area using Virkotype as a medium. The discriminability of these plus additional symbols reproduced in vacuum formed plastic was checked using 92 students of both sexes from the Ohio and Western Pennsylvania residential schools. These subjects were grouped in grade levels as before with 23 subjects included at each level. Figure 3 pictures the 13 areal symbols studied.

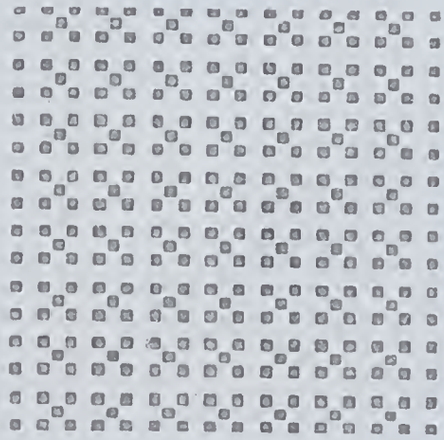
Table 11 gives the error matrix for this set of symbols. Inspection reveals that seven of these (A, E, F, G, H, K, and L) meet all criteria for acceptance. Differences among grade groups for median discriminability of acceptable symbols were tested for significance using the Kruskal-Wallis test. The resulting H value of 6.30 fell below the value of 7.82 needed for significance at the 5% level of confidence. Medians and ranges for individual scores within grade groups are given in Table 12.

FIGURE 3

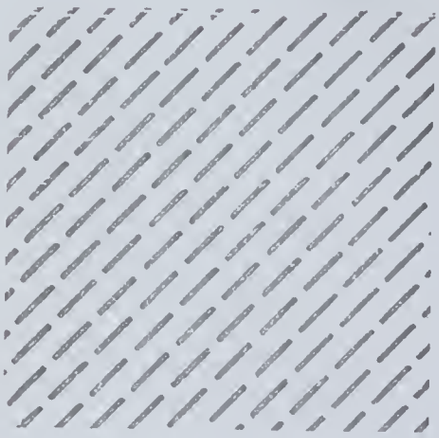
AREAL PATTERNS REPRODUCED IN VACUUM FORMED PLASTIC

FOR POSSIBLE USE AS TACTUAL SYMBOLS.

A



B



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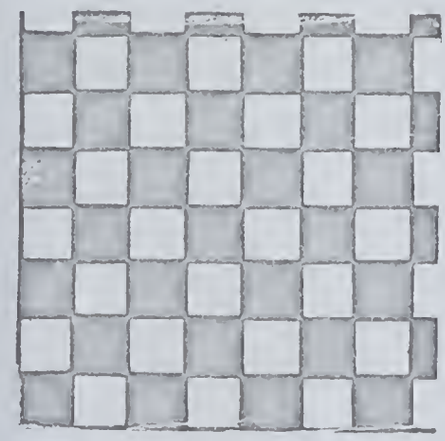

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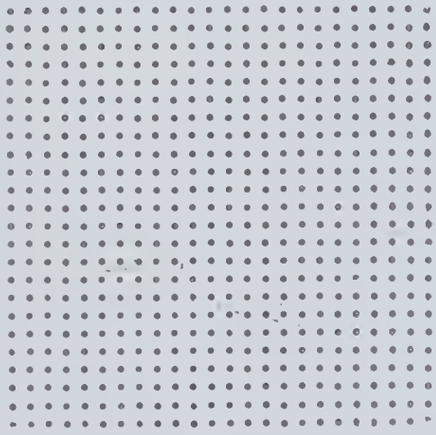

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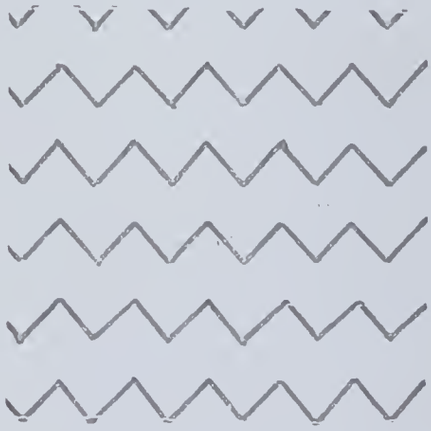

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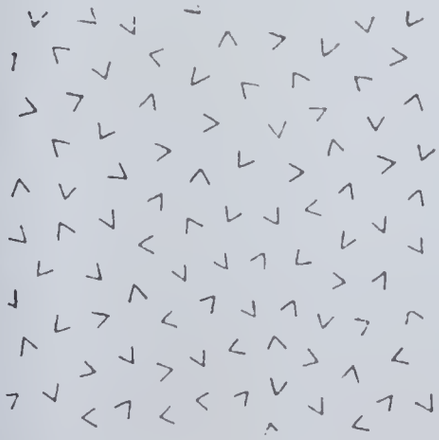
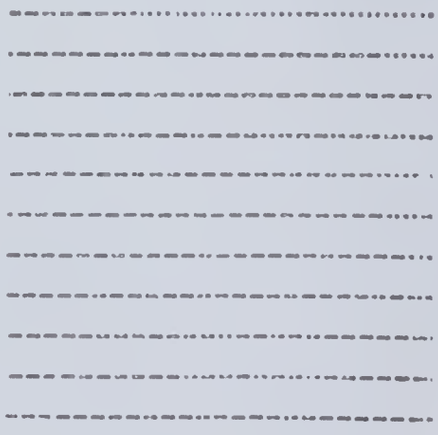


G

H



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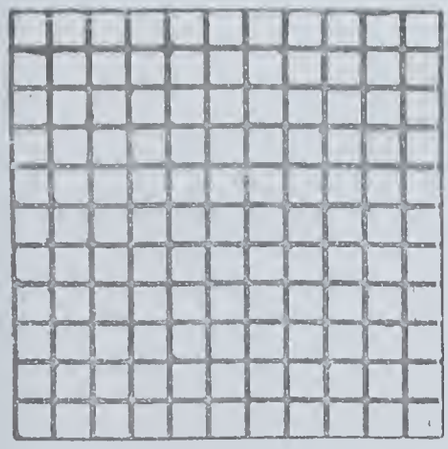
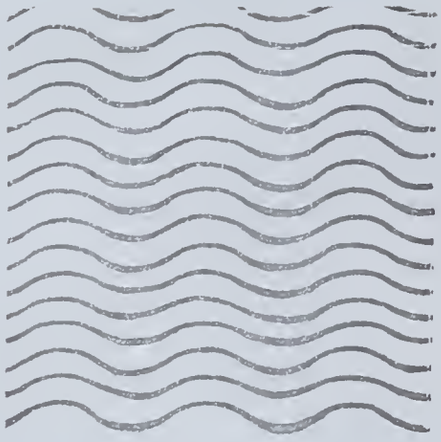


L

I is like H with the lines going vertically.

K is like J with the lines going vertically.



M

TABLE 11

Percent of Error in Discriminating Difference or Likeness in Each of 91 Combinations of 13 Different Areal Symbols (N=92)

Areas	A	B	C	D	E	F	G	H	I	J	K	L	M
A	09	01	04	02	01	02	00	02	02	00	02	02	06
B		06	10	02	36	00	02	05	03	02	02	04	08
C			30	02	02	00	03	03	04	01	02	02	20
D				14	01	18	00	01	02	00	01	02	01
E					06	00	02	10	13	03	02	01	03
F						09	02	01	01	01	02	05	01
G							10	00	00	01	04	01	00
H								08	13	40	02	01	13
I									04	02	29	00	06
J										04	08	02	02
K											06	02	01
L												08	04
M													24

TABLE 12

Areal Symbols: Median Number of Correct Discriminations and Ranges of Correct Discriminations for 28 Pairs of 6 Acceptable Symbols for Subjects Grouped by Grade Level.

	Grades			
	4-5	6-7	8-9	10-12
Median	27.8	27.9	28.0	28.0
Range	18-28	26-28	25-28	26-28
N	23	23	23	23

Results of the Associative Learning Experiments

As indicated earlier, the purpose of this phase of the study was to determine how readily the tactual stimuli previously identified as discriminable could be associated with verbal stimuli and how well these associations could be retained. The procedure followed was that outlined under General Methodology.

Results for individual subjects for learning and relearning verbal associations for tactual symbols can be found in Table 13. All subjects learned the associations easily and retention after 28 days was quite high in both cases. In the case of the point symbols, initial learning was so easy that no savings could be demonstrated after 28 days.

Ease of learning and relearning is clearly reflected in Tables 14 and 15 which give the average number of errors for linear and point symbols respectively for the learning and relearning phases of the experiment. Variability among symbols for this critorion is slight.

TABLE 13

Number of trials Required to Learn and Relearn After 28 Days Associations between Tactual and Verbal Symbols.

	Linear Symbols			Point Symbols		
	Trials			Trials		
Subject	Learning	Relearning	Savings	Learning	Relearning	Savings
1	2	1	1	1	1	0
2	2	1	1	1	3	-2
3	3	2	1	2	2	0
4	10	3	7	2	3	-1
5	11	3	8	2	4	-2
6	15	3	12	3	2	1
7	11	4	7	2	2	0
8	12	5	7	3	5	-2
9	14	5	9	3	3	0
10	16	8	8	11	5	6
11	14	11	3			
Mean	10.0	4.18	5.82	3.0	3.0	0.0

TABLE 14

Average Number of Errors for Each Linear Symbol during Learning and Relearning Associations for Verbal Symbols (N=11)

Symbol			
Tactual	Verbal	Initial Learning	Relearning
C	Alpha	6.4	1.8
E	Echo	4.0	1.2
F	Foxtrot	4.5	.5
G	Oscar	3.2	1.6
H	Poppa	4.9	1.5
I	Romeo	4.3	1.0
J	Tango	4.3	.9
K	Victor	3.2	1.0
M	X-ray	2.2	.7

It will be noted from Table 14 that three linear symbols (E, G, and H) that failed to meet the criterion of no more than 10% error on self-comparisons are included in the association study (See Table 6). A similar case exists for point symbols B and N in addition to which the confusion between symbols C and N is 1%

greater than the criterion allows (See Table 9). Mean error scores for learning and relearning for these symbols are well within the range for the total group of symbols which indicates that the criterion used may have been too stringent.

TABLE 15

Average Number of Errors for Each Point Symbol during Learning and Relearning Association for Verbal Symbols (N=10)

Symbol			
Tactual	Verbal	Initial Learning	Relearning
B	Alpha	1.4	.9
C	Echo	2.3	1.6
F	Foxtrot	1.1	.9
G	Oscar	.3	.5
I	Romeo	.4	.4
K	Tango	.3	.8
M	Victor	.3	.7
N	X-ray	1.3	1.2

The ease with which the sets of symbols were learned renders unnecessary further intensive analysis of the data as originally planned. Efforts to establish the relationship between degree of discriminability of symbols are frustrated by extreme restriction of range for the variables involved.

Conclusions:

The results of these studies demonstrate that sets of tactual symbols for areas, lines, and points can be identified which are highly discriminable and which can easily be learned and remembered. Therefore, the primary symbolic material necessary for the design of tactual graphics is now available.

Recommendations:

It has been recommended to the Tangible Apparatus Committee of the American Printing House for the Blind that the symbols identified in this study immediately be used in the production of several experimental maps. It has also been recommended that investigation be made of the use of the symbols in other types of graphic communications.

Several problems for future research remain. These problems are basically the same whether they apply to maps, graphs, charts, or diagrams:

a. What is the minimal two dimensional size at which tactual symbols for area can be discriminated?
b. How may tactual symbols for lines, points, and areas be combined to provide for maximum discriminability? This is essentially the figure-ground problem of making salient points of a graphic communication stand out so as to be easily noticeable.
c. How much information can be effectively communicated in a single tactual map, chart, diagram, or graph?

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Morris, June E., & Nolan, C. Y. Discriminability of tactual patterns. Int. J. Educ. Blind, 1961, 11, 50-54.

Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1956.

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Tactual Symbols for the Blind

Summary: OVR-RD-587

Project Director: Carson Y. Nolan
Research Assistant: June E. Morris

Rehabilitation of the blind requires embossed materials which employ both verbal and graphic forms of communication. Braille, which is highly developed and standardized, fills the requirement for embossed verbal communication. However, the means available for embossed graphic communication, i. e. maps, graphs, charts, and diagrams, are still relatively crude. Lack of identification of clearly discriminable tactual symbols and lack of knowledge of factors that determine tactual figure-ground relations have seriously impoded development in this area.

Three types of symbols; areal, linear, and point, are needed for graphic communication. The number of discriminable tactual symbols possible in any given size appears dependent upon the medium in which symbols are reproduced. For example, the number of small symbols which can be reproduced through embossing paper is extremely limited. In earlier research, the authors, using Virkotype printing as a medium, identified eight discrete symbols for area and demonstrated that blind students easily could learn to recognize these and retained this skill after a 28 day interval. The purpose of this project was to identify sets of symbols for lines and points that were highly discriminable and to determine how easily these could be learned and recalled by blind students.

The discrimination phase of the project went through several stages all of which followed the same general design. Blind students of both sexes in grades 4-12 served as subjects. The discriminability of the symbols was tested using the method of pair comparison. Every symbol was paired with itself and every other symbol resulting in $n(n-1)/2 + n$ combinations of stimuli for each set studied. The task for each subject was to judge whether the stimuli in the pair were alike or different. The stimuli were mounted on cards and presented in random order.

Criteria for acceptance of a symbol as discriminate were (1) that average confusion with other acceptable symbols should be 5% or less and (2) that confusion with itself or any other single symbol acceptable by criterion (1) should be 10% or less. In addition, for any set of symbols acceptable by criteria (1) and (2), there should be no significant differences in discriminability of acceptable symbols among children in grades ranging from 4-12.

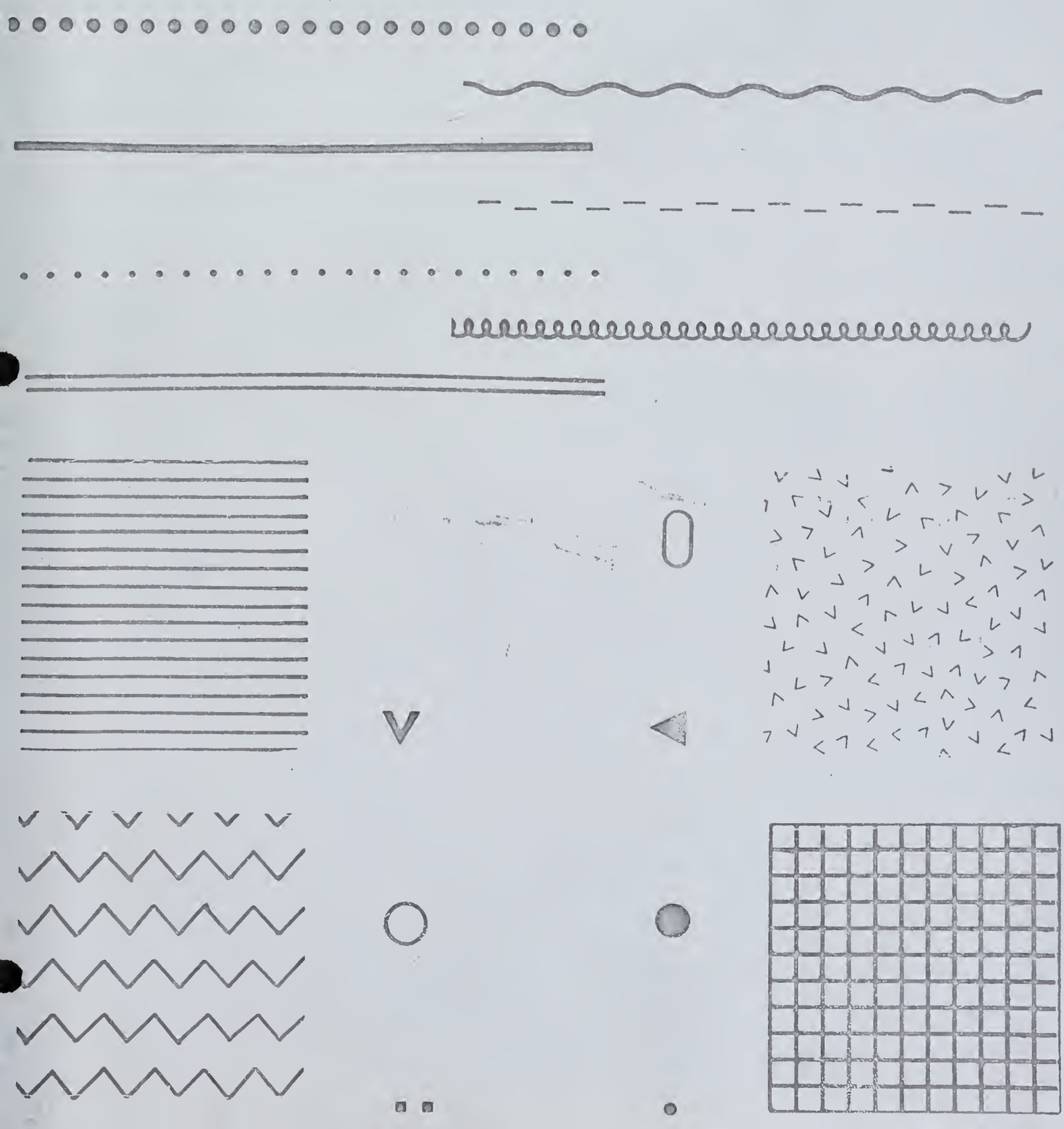
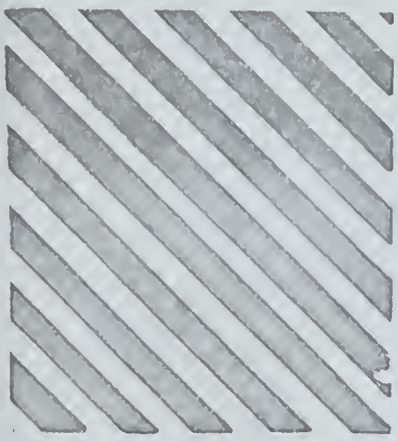
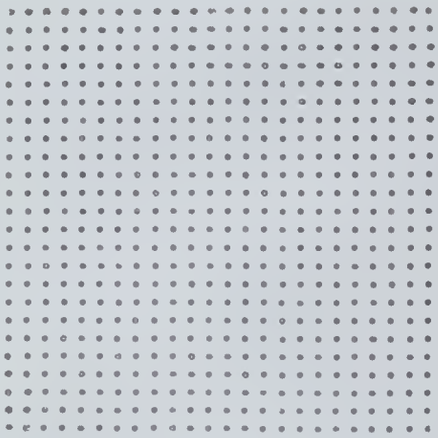
The initial efforts using Virkotype printing were unsuccessful. The studies were repeated using vacuum formed plastic as a medium. These efforts resulted in

the identification of at least seven linear symbols, eight point symbols, and seven areal symbols which met the criteria described above. Pictures of these patterns are attached to this summary. There were no differences among blind children at different grade levels in ability to recognize these symbols and this ability was not related to chronological age or sex.

The learning phase of the project dealt only with the linear and point symbols since the authors had previously demonstrated that the areal symbols were learned readily. The procedure was identical for each set of symbols and only the symbols of proven discriminability were used. Each symbol was paired with a letter of the International Phonetic Alphabet. The task for the subject was to learn to associate the tactual symbol with its phonetic name.

To accomplish this, each subject was given 10 series of trials for each of 10 consecutive days or until recognition of the set of symbols was perfect for two consecutive series of trials. The paired-associates method of presentation was employed. During the first two series for each type, the subject felt the symbol for 15 seconds after which time the phonetic name was presented auditorily. For the rest of the series, the subject was allowed 15 seconds to feel each symbol and give its correct name. At the end of this period the correct name was given auditorily and the next symbol presented. The order of presentation within each series was randomized using a table of random numbers. After 28 days the recall training was given. Procedure for this duplicated that for association training except the procedure for the first two series of any type symbol was omitted.

Ten blind students of both sexes in grades 4-12 served as subjects. All learned the required associations quite easily and retention after 28 days was high in both cases.

FIGURE 4

PATTERNS IDENTIFIED AS HIGHLY DISCRIMINABLE